Chapter 1

Ion Source Equipment Testing

October 10, 2013

1.1 Source Arc Power Supply

1.1.1 State Controls

1. PSARC (ON,OFF) (On indicates that the high voltage is on. Off indicates that the high voltage is off)

   1) Press the On button in the operations console. Observe the following: Does the PS come on? Does Source:Arc:On:Status go from zero to 1 when you do this? Does Source:Arc:Condition:Initializing:Status get set to 1 then 0? Does Source:Arc:Reset:Interlocks:Write go to 1, then 0 again?

   2) Set Source:CommError:Status and Source:HardwareError:Status to false, then turn on and see if this clears.

   4) Does pressing the Off button at the operations console turn off the PS? When you press off, does the "Shutting Down" light flash in both the operations and status display?

   5) On the Operations Console, and Status display, observe that PREAD says zero for PSARC when the PS is off.

   6) Place the device in local mode, and attempt to turn on the PS. You shouldn't be

able to do this.

7) When you turn on the device locally, make sure SWM:Condition:Initializing:Status gets set to 1 then 0.

2. Source Initialize (Includes both PS Arc and Gas Control)

   Press the Initialize button in the operations console and observe the following: Does the PV Source:Condition:Initializing:Status go from 0 to 1, then back to 0 during this process? Ensure that it flashes "Initializing" in Yellow on the operations and status display screen.

   Try setting Set Source:CommError:Status and Source:HardwareError:Status to false, then press Initialize and see if they go back to true. With the RF on and 0 cathode current, and verify that you cannot press the Initialize button. Then type caput Source:Init:String.PROC 1 and verify the the PS does not initialize (you should see a message "can't initialize, beam on" or something like that.

3. Source Reset (Includes both PS Arc and Gas Control)

   With the PSARC Off and in remote mode, turn off the cooling water. Verify that Device Interlock shows up in ops dipslay, and that he status display terminal shows the two cooilng interlcoks. Try turning on the PSARC, and verify that you are prevented from doing so, and the appropriate message (the 2 cooing interlocks) appears in the message board. Try turning the PSARC on locally, and verify that it won't go on. Then turn the water back on and observe that the PS cooling interlocks still exist. Then, press the Reset button on the operations console, and observe the interlocks clear on both screens, and that you can now turn on the PSARC.

4. Dose Rate Servo (ON/OFF)

Dose Rate Servo (ON/OFF)

During a standard therapy treatment run a feedback loop from the Dose Monitor Controller (DMC) keeps the dose rate constant. An analog feedback signal to the PSARC controls the PSARC output current and thus the dose rate. There are times, such as when there are higher than normal beam losses, that it is preferred to manually control the PSARC output current (and dose rate) without the feedback effect from the DMC. This is accomplished by providing a control at the Cyclotron Control Console that can disconnect the DMC feedback signal from the PSARC control and thus turn off the DMC Dose Rate Servo signal.

Standby 1 to Standby 2 Transition

When the system is commanded to transition to the Standby 2 state as described in section **??** the PSARC is turned on.

Have to just make sure it goes up the first time they hit SB1.

Standby 2 to Standby 1 Transition

When the system is commanded to transition to the Standby 2 state as described in section **??** the PSARC is turned off.

Have to just make sure it turns off the first time they hit SB1.

1.1.2 State Monitors

1. Control Voltage (MOD1PS-13) Status

   Does this show up?

2. Spellman Control Power (On,Off)

   Does this show up?

3. PSARC Main Key (On,Off)

   Does this show up?

4. PSARC (ON,OFF) (On indicates that the high voltage is on. Off indicates that the high voltage is off)

   Does this show up?

5. PSARC at Power Limit

   Does this show up?

6. Potential Short in Source (When calculated resistance is close to 20 kΩ for N=1 and 2 kΩ for N=2)

   Does this show up?

7. Current ¿ 200 mA (For Proton Beam Only)

   Does this show up?

8. Dose Rate Servo (ON,OFF)

   Does this show up?

9. HV Source Selection Switch (N=1,N=2)

   Does this show up?

10. Source Communication Error (Includes both PS Arc and Gas Control)

    Does this show up?

11. Source Initializing (Includes both PS Arc and Gas Control)

    Does this show up?

12. PS Arc Shutting Down

    Does this show up?

13. Source Watchdog (Includes both PS Arc and Gas Control)

    Does this show up?

14. Upper Source Cooling

    Does this show up?

15. Lower Source Cooling

    Does this show up?

16. Upper Cathode in Position

    Does this show up?

17. Lower Cathode in Position

    Does this show up?

18. Resistor Box Cover

    Does this show up?

19. Therapy Room Emergency Loop

    Does this show up?

Device Interlocks

PSARC Device Interlocks: (Occurrence of interlock will turn off the PSARC and not allow the PSARC to be turned on)

1. Upper Source Cooling - Reset to Remove Latch

   With the PS on, turn off the water. Verify that the PS turns off, and you can't turn it back on.

2. Lower Source Cooling - Reset to Remove Latch

   With the PS on, turn off the water. Verify that the PS turns off, and you can't turn it back on.

3. Upper Cathode in Position - Reset to Remove Latch

   With the PS on, turn off the water. Verify that the PS turns off, and you can't turn it back on.

4. Lower Cathode in Position - Reset to Remove Latch

   With the PS on, turn off the water. Verify that the PS turns off, and you can't turn it back on.

5. Resistor Box Cover - Reset to Remove Latch

   With the PS on, turn off the water. Verify that the PS turns off, and you can't turn it back on.

6. Therapy Room Emergency Loop - Reset to Remove Latch

   With the PS on, turn off the water. Verify that the PS turns off, and you can't turn it back on.

Particle Beam Interlocks

PSARC Particle Beam Interlocks: (Occurrence of interlock will prevent RF system from attempting to accelerate a particle beam) (Items in italics are detected in the IOC and sent to the PLC as part of the PSARC No Fault/No Error information)

1. PSARC Power Supply Off - Non-latching

   Write Source:Condition:Initializing:Status from 0 to 1, and verify that Source:SystemOK:Standby2:Sta
   goes from 1 to 0.

2. HV Source Selection Switch Incorrect for Particle Selected - Non-latching

   Write Source:Condition:Initializing:Status from 0 to 1, and verify that Source:SystemOK:Standby2:Status goes from 1 to 0.

3. Source Watchdog - Initialize to Remove Latch (Includes both PS Arc and Gas Control)

   Write Source:Condition:Initializing:Status from 0 to 1, and verify that Source:SystemOK:Standby2:Status goes from 1 to 0.

4. PSARC Shutting Down - Non-latching

   Write Source:Condition:Initializing:Status from 0 to 1, and verify that Source:SystemOK:Standby2:Status goes from 1 to 0.

5. Source Initializing - Non-latching (Includes both PS Arc and Gas Control)

   Write Source:Condition:Initializing:Status from 0 to 1, and verify that Source:SystemOK:Standby2:Status goes from 1 to 0.

6. Source Communication Error - Initialize to remove latch (Includes both PS Arc and Gas Control)

   Write Source:Condition:Initializing:Status from 0 to 1, and verify that Source:SystemOK:Standby2:Status goes from 1 to 0.

Note: Future implementation may include interlocks for current/voltage/power outside tolerance windows.

1.1.3 Safety

Loss of control of the PSHV may result in an excessive amount of particle beam being produced. Currently, the only protection against this is provided by the particle beam hardwired safety interlock system (HSIS) (section **??**) that monitors the particle beam position and beam losses described in section **??**. In the future we may add additional protection in the control system. Adding additional protection at this time would require signifigant resources and vased on our 20+ years operating experience we feel that this feature can wait.

1.1.4 Analog Control Parameters

PSET is not handled by the computer control system. Analog control is done via hardwired potentiometers and direct analog feedback loops.

1. None

1.1.5 Parameter Limits

There are no analog parameters limits handled by the computer control system. All analog control is done via hardwired potentiometers and direct analog feedback loops.

1.1.6 Analog Display Parameters

As far as I know, just make sure the Source current and voltage are being read correctly by the acromag. Those PVs are Source:Arc:Curr:Read and Source:Arc:Volt:Read.

1. PSARC Voltage PREAD n.nn kV
2. PSARC Power PREAD nnnn W
3. PSARC Current PREAD nnn mA
4. PSARC Current PLOW nnn mA
5. PSARC Current PHIGH nnn mA
6. PSARC Circuit Resistance PREAD n.n kΩ (Only calculated if PSARC current PREAD $\geq$ 1.0 mA)

1.2 Source Gas Handling

1.2.1 State Controls

Have to see if these are just physical buttons, or also exist in epics...

1. Particle Type Select (Protons, H2+, Deutrons, 3-Helium, Alpha) (This control is not available for the operator to directly modify at the Cyclotron Control Console. The particle type is indicated in the particle type saved settings (section **??**).
2. N=1 Valve (Open,Close)

   Have to see if these are just physical buttons, or also exist in epics...

3. N=2 Valve (Open,Close)
   Have to see if these are just physical buttons, or also exist in epics...
4. Proton Valve (Open,Close)
   Have to see if these are just physical buttons, or also exist in epics...
5. H2+ Valve (Open,Close)
   Have to see if these are just physical buttons, or also exist in epics...
6. 3-Helium Valve (Open,Close)
   Have to see if these are just physical buttons, or also exist in epics...
7. 4-Helium Valve (Open,Close)
   Have to see if these are just physical buttons, or also exist in epics...
8. Air Valve (Open,Close)
   Have to see if these are just physical buttons, or also exist in epics...
9. SVP Valve (Open,Close)
   Have to see if these are just physical buttons, or also exist in epics...
10. Source Initialize (Includes both PS Arc and Gas Control)
    This button was tested above, I believe

Standby 1 to Standby 2 Transition

When the system is commanded to transition to the Standby 2 state as described in section **??** the gas manifold is pumped out by the service pump and then the gas selection and chimney valves are opened as required by the particle setting loaded.

When you press SB2, verify that all this happens.

Standby 2 to Standby 1 Transition

When the system is commanded to transition to the Standby 1 state as described in section **??** the gas selection and chimney valves are closed.

When you press SB1, verify that all this happens, and that the gas flow Source:Gas:Flow:SendSet goes to 0.

1.2.2 State Monitors

1. Source Initializing (Includes both PS Arc and Gas Control)

   This button was tested above, I believe

2. Gas Selection Local

   This button was tested above, I believe

3. Selected gas type (Hydrogen, Deuterium, Helium 3, Helium 4, Air, None) (Note: Air may only be selected on the front panel of the gas selection unit and when it is in local. None is selected when the system is in Standby 1, and may also be selected on the front panel of the gas selection unit and when it is in local.)

   This button was tested above, I believe

4. Service Pump (On,Off)

   This button was tested above, I believe

5. Service Pump Gas Manifold Valve (Open,Closed)

   This button was tested above, I believe

6. Source Communication Error (Includes both PS Arc and Gas Control)

   This button was tested above, I believe

7. Source Watchdog (Includes both PS Arc and Gas Control)

   This button was tested above, I believe

Device Interlocks

Gas Handling System Device Interlocks: (Occurrence of interlock will prevent the Gas Handling System from turning on.)

1. None

Gas Valve Device Interlocks: (Occurrence of interlock will prevent certain valves on the gas handling manifold from opening. Note: These are all handled in the PLC)

1. Gas Selection Valve Open (Only one gas selection valve may be open at any one time. The service pump valve may not be opened if a gas selection valve is open.) - Non-latching

   This button was tested above, I believe

2. Chimney Selection Valve Open (Only one chimney valve may be open at any one time. The service pump valve may not be opened if a chimney valve is open.) - Non-latching

   This button was tested above, I believe

3. Service Pump Valve Open (No gas select valves or chimney valves may be opened if the service pump valve is open) - Non-Latching

   This button was tested above, I believe

4. Cyclotron Vacuum (No gas select valves or chimney valves may be open if high vacuum is not ok in the cyclotron vacuum tank.) - Non-Latching

   This button was tested above, I believe

Particle Beam Interlocks

Gas Handling System Particle Beam Interlocks: (Occurrence of interlock will prevent RF system from attempting to accelerate a particle beam.)

1. Gas Type expected by IOC $\neq$ Gas Type commanded by PLC - Non-latching

   This button was tested above, I believe

2. Source Chimney Selection Incorrect for Particle Selected - Non-latching

   This button was tested above, I believe

3. Extractor Servo Communication Fault - Initialize to remove latch (Includes both PS Arc and Gas Control)

   This button was tested above, I believe

4. Gas Servo PREAD $\geq$ PHIGH - Non-latching

   This button was tested above, I believe

5. Gas Servo PREAD $\leq$ PLOW - Non-latching

   This button was tested above, I believe

6. Gas Servo |PREAD-PSET| ≥ PDiff - Non-latching
   This button was tested above, I believe
7. Source Watchdog - Initialize to Remove Latch (Includes both PS Arc and Gas Control)
   This button was tested above, I believe
8. Source Initializing - Non-latching (Includes both PS Arc and Gas Control)
   This button was tested above, I believe

1.2.3 Safety

1.2.4 Analog Control Parameters

1. Gas Flow PSET nn.nn SCCM
   This button was tested above, I believe
2. Gas Flow PLOW nn.nn SCCM
   This button was tested above, I believe
3. Gas Flow PHIGH nn.nn SCCM
   This button was tested above, I believe
4. Gas Flow PDIFF nn.nn SCCM
   This button was tested above, I believe
5. Gas Flow PSEN n
   This button was tested above, I believe

Parameter Limits

1. Gas Flow MaxLimit = 10 sccm
   This button was tested above, I believe
2. Gas Flow MinLimit = 0 sccm
   This button was tested above, I believe

1.2.5 Analog Display Parameters

1. Gas Flow PSET nn.nn SCCM
   This button was tested above, I believe
2. Gas Flow PREAD nn.nn SCCM
   This button was tested above, I believe
3. Gas Flow PLOW nn.nn SCCM
   This button was tested above, I believe
4. Gas Flow PHIGH nn.nn SCCM
   This button was tested above, I believe
5. Gas Flow PDIFF nn.nn SCCM
   This button was tested above, I believe
6. Gas Flow PSEN n
   This button was tested above, I believe

Chapter 2

Ion Source Operations Console Testing

2.0.6 Ion Source Subsystem Operations

Control of the Ion Source System is divided into two groups: the Gas Handling System and the Arc Power Supply (PSARC). The Ion Source System is selected by clicking the virtual "Ion Source System" button in the Subsystem Select region of the display.

Title

The title of the system will be Ion Source System. The color of the title bar will be orange.

Draggable Objects

1. None

State Controls

1. Reset Ion Source System
   This button was tested above, I believe

State Indicators

1. None

Arc Power Supply (PSARC) Subsystem Operations

Draggable Objects

1. None

State Controls

1. (ON,OFF)
   This button was tested above, I believe
2. Initialize (Button is disabled if device does not have control power or if RF in High Power mode)
   This button was tested above, I believe

State Indicators

1. (ON,OFF)
   This button was tested above, I believe
2. Initializing - Flashing Yellow
   This button was tested above, I believe
3. Device Interlock - Red
   This button was tested above, I believe
4. Communication Fault - Fuchsia
   This button was tested above, I believe
5. Process Heartbeat - Fuchsia
   This button was tested above, I believe

Arc Power Supply (PSARC) Device Operations

Because there are no computer controllable parameters for the PSARC other than On/Off, there is no Device Operations panel associated with the PSARC.

Gas Flow Subsystem Operations

Draggable Objects

1. "Gas Flow" label. - Will assign Gas Flow parameter to Tuning Module or open Gas Flow Display in Device Operations region.

   This button was tested above, I believe

State Controls

1. Initialize (Button is disabled if device does not have control power or if RF in High Power mode)

   This button was tested above, I believe

State Indicators

1. Gas Select Local

   This button was tested above, I believe

2. Initializing - Flashing Yellow

   This button was tested above, I believe

3. Device Interlock - Red

   This button was tested above, I believe

4. Communication Fault - Fuchsia

   This button was tested above, I believe

5. Process Heartbeat - Fuchsia

   This button was tested above, I believe

Gas Flow Device Operations

Title The title of the system will be Gas Flow. The color of the title bar will be dark purple.

State Controls

1. None

State Indicators

1. None

Analog Control Parameters

1. Gas Flow PSET nn.nn SCCM
   This button was tested above, I believe
2. Gas Flow PLOW nn.nn SCCM
   This button was tested above, I believe
3. Gas Flow PHIGH nn.nn SCCM
   This button was tested above, I believe
4. Gas Flow PDIFF nn.nn SCCM
   This button was tested above, I believe
5. Gas Flow PSEN n
   This button was tested above, I believe

Analog Display Parameters

1. Gas Flow PSET nn.nn SCCM
   This button was tested above, I believe

2. Gas Flow PREAD nn.nn SCCM

   This button was tested above, I believe

3. Gas Flow PLOW nn.nn SCCM

   This button was tested above, I believe

4. Gas Flow PHIGH nn.nn SCCM

   This button was tested above, I believe

5. Gas Flow PDIFF nn.nn SCCM

   This button was tested above, I believe

6. Gas Flow PSEN n

   This button was tested above, I believe

Chapter 3

Ion Source Status Testing

3.0.7 Ion Source system

Title

The title of the display is Ion Source System Status. The color of the title bar is orange.

Arc Power Supply (PSARC)

State Monitors

1. PSARC (ON,OFF)

   This button was tested above, I believe

2. Initializing

   This button was tested above, I believe

3. Shutting Down

   This button was tested above, I believe

4. MOD1PS-13 Voltage Status

   This button was tested above, I believe

5. Spellman Control Power (On,Off)
   This button was tested above, I believe
6. PSARC Main Key (On,Off)
   This button was tested above, I believe
7. High Voltage (ON,OFF)
   This button was tested above, I believe
8. PSARC at Power Limit
   This button was tested above, I believe
9. Potential Short in Source (When calculated resistance is close to 20 kΩ for N=1 and 2 kΩ for N=2)
   This button was tested above, I believe
10. Current ¿ 200 mA (For Proton Beam Only)
    This button was tested above, I believe
11. Local
    This button was tested above, I believe
12. Dose Rate Servo (ON,OFF)
    This button was tested above, I believe
13. HV Source Selection Switch (N=1,N=2)
    This button was tested above, I believe
14. Upper Source Cooling
    This button was tested above, I believe
15. Lower Source Cooling
    This button was tested above, I believe
16. Upper Cathode in Position
    This button was tested above, I believe
17. Lower Cathode in Position
    This button was tested above, I believe
18. Resistor Box Cover
    This button was tested above, I believe

19. Therapy Room Emergency Loop

    This button was tested above, I believe

20. Source Heartbeat

    This button was tested above, I believe

21. Source Communication Fault

    This button was tested above, I believe

The HV Source Selection should be displayed in a graphical format in a diagram that includes the appropriate series resistors for the two source chimneys.

Analog Parameters

1. PSARC Voltage PREAD n.nn kV

   This button was tested above, I believe

2. PSARC Power PREAD nnnn W

   This button was tested above, I believe

3. PSARC Current PREAD nn.n mA

   This button was tested above, I believe

4. PSARC Circuit Resistance PREAD n.n kΩ (Only calculated if PSARC current PREAD $\geq$ 1.0 mA)

   This button was tested above, I believe

Ion Source Gas Handling

The source gas handling status display is a graphical representation of the source gas subsystem parameters, rather than a display of simple tables and text. The display is designed in a manner consistent with section **??** as described in subsection **??**. Vacuum components are displayed using the DIN 28 401 standard for vacuum symbols as much as possible. A general guide to the CNTS Source Gas Handling System is shown in fig. 3.1

Figure 3.1: Source Gas Handling System Layout

Source Gas Handling system display conventions

In order to provide the cyclotron operator with a quick overview of the status of the gas handling system system, gas chambers are displayed pipes or chambers with colors corresponding to the gas in the chamber. There are four gas types available to the ion source: Hydrogen, Deuterium, Helium-3, and Helium-4. The color representing each gas should be clearly unique. Additionally, air may be allowed in the gas handling system and the system may be pumped out with the service pump. Air should be indicated with whatever color is used for the background of the display. The chamber should be displayed as white while it is being pumped down. Any pipe or chamber to which all valves are closed should be displayed as black indicating that the section of pipe or chamber is not in use.

State Monitors

1. Particle Type Select (Protons, H2+, Deuterons, 3-Helium, Alphas)
   This button was tested above, I believe
2. Local
   This button was tested above, I believe
3. Hydrogen Gas Valve (Open,Closed)
   This button was tested above, I believe
4. Deuterium Gas Valve (Open,Closed)
   This button was tested above, I believe
5. Helium 3 Gas Valve (Open,Closed)
   This button was tested above, I believe
6. Helium 4 Gas Valve (Open,Closed)
   This button was tested above, I believe
7. Air Valve (Open,Closed)
   This button was tested above, I believe

8. N=1 Chimney Gas Valve (Open,Closed)
   This button was tested above, I believe
9. N=1 Chimney Gas Valve (Open,Closed)
   This button was tested above, I believe
10. Service Pump Valve (Open,Closed)
    This button was tested above, I believe
11. Service Pump (On,Off)
    This button was tested above, I believe
12. Source Heartbeat - Initialize to remove latch
    This button was tested above, I believe
13. Source Communication Fault - Initialize to remove latch
    This button was tested above, I believe
14. Initializing
    This button was tested above, I believe

Analog Parameters

1. Gas Flow PSET nn.nn SCCM
   This button was tested above, I believe
2. Gas Flow PREAD nn.nn SCCM
   This button was tested above, I believe
3. Gas Flow PLOW nn.nn SCCM
   This button was tested above, I believe
4. Gas Flow PHIGH nn.nn SCCM
   This button was tested above, I believe
5. Gas Flow PREAD n.nn ccm
   This button was tested above, I believe